



EPA Cool Pavements Workshop

Beating the Heat from Urban Runoff



*Don Wayne, U.S. EPA—Nonpoint Source Control Branch
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Global warming is:

- aggressively researched
- international news
- fodder for Hollywood movies

Thermal impacts on waterbodies from urbanization is:

- Under-monitored & reported
 - under-researched
 - easily proven



True or False:

The Clean Water Act addresses heat pollution

True!



True!

The CWA mentions “thermal” 18 times (e.g., “thermal discharges”, “thermal water quality standards”, “thermal loads”, “thermal components”)

303(d)(1)(B) Each State shall identify those waters or parts thereof within its boundaries for which controls on thermal discharges under section 301 are not stringent enough to assure protection and propagation of a balanced indigenous population of shellfish, fish, and wildlife.

303(d)(1)(D) Each State shall estimate for the waters identified in paragraph (1)(D) of this subsection the total maximum daily thermal load required to assure protection and propagation of a balanced, indigenous population of shellfish, fish and wildlife...



EPA's Phase 2 Stormwater Rule

- Most localities over 50,000 people must have a stormwater discharge permit for their "MS4s"
- Temperature is cited as one of EPA's "Pollutants of Concern"
- No specific monitoring is required
- Temperature may be addressed through Phase II permits where TMDLs have been developed



Temperature TMDLs

- TMDL = Total Maximum Daily Load
- 25,000+ U.S. waterbodies listed as impaired (46,000+ pollutant impairments in those waterbodies)
- >2,000 listings (~4%) of impairments are for temperature
- To date, 167 "Temperature TMDLs" have been developed
- Most of these have a nonpoint source component (includes urban stormwater, agriculture, forestry, hydromodification)

Water Temperature:

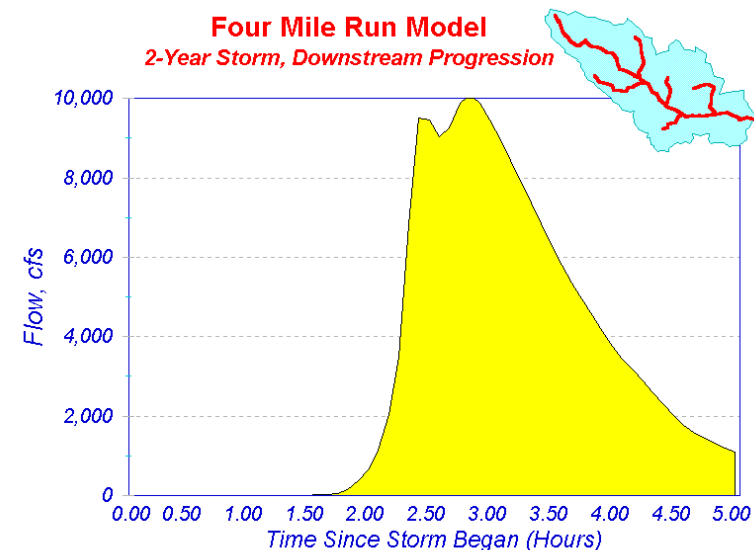
- Affects all aspects of aquatic life, especially metabolism & reproduction
- Range determines which species can survive





Species Tolerate Gradual Change Better than Rapid Change.

- Change of 5°F in 5 hours can induce stress in most desirable species
- Urban areas contribute 8x more storm runoff than woodland areas of same size
- Time of concentration is much quicker as imperviousness increases
- Changes of +8 °F in < 1hour after summer squalls in many ultra-urban streams



Effects of Thermal Impacts

- Species diversity decreases.
- Trout species are especially vulnerable.
(GMU's Dr. Kelso documented trout loss in Difficult Run in 1970s)
- American Shad are vulnerable due to their anadromous migrating pattern;



**large-scale "mystery" fish kills correspond with migration into urban fresh water streams.
(state agency fish kill files)**



Temperature research

- ...is very limited in the U.S. Most focuses on impacts from cooling towers and forestry.
- New research is coming out of Great Lakes region.
- MWCOCG (Galli, 1990) analyzed Maryland streams and determined...

avg. **summer** stream temps. increase by **0.14 °F**
for every **1%** increase in imperviousness

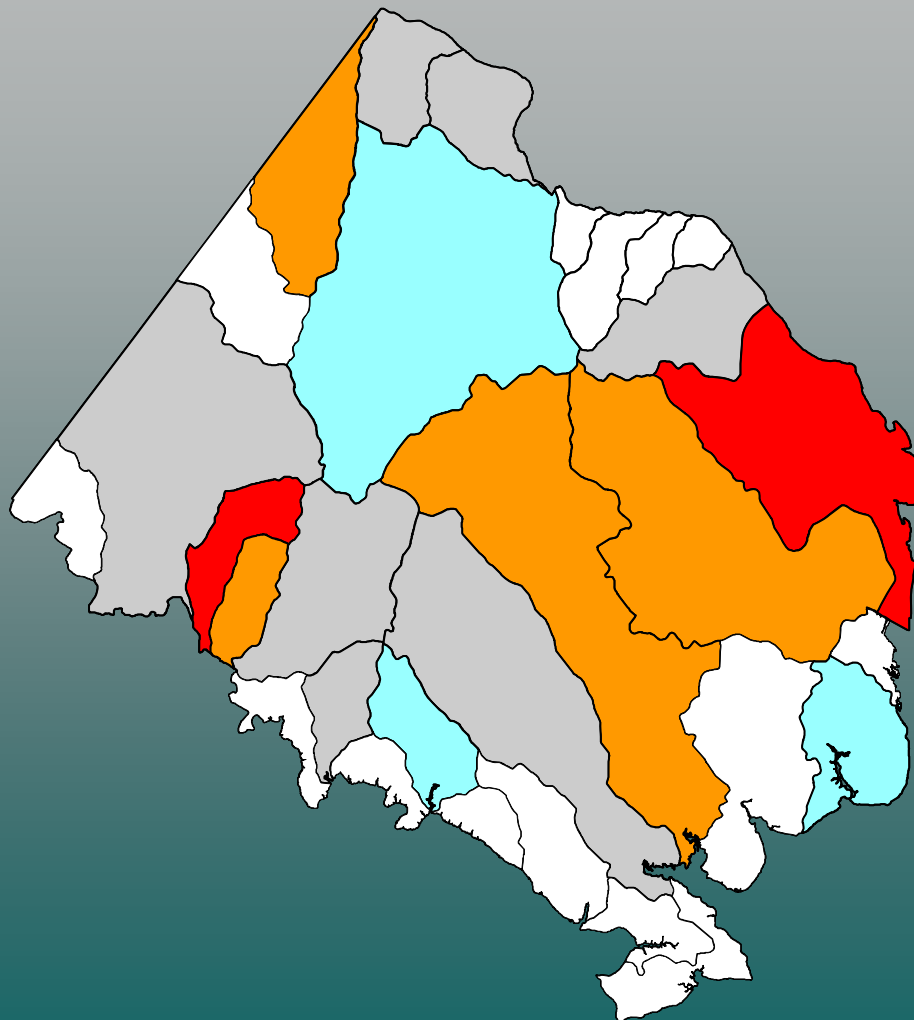
(based on 1 season and 5 sites)



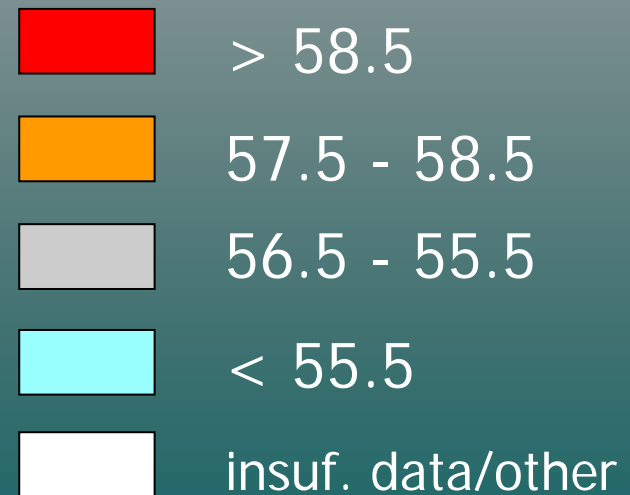
1998 NVPDC analysis of Fairfax Co. (VA) water quality database

- FCHD survey is the most detailed, long-term, continuous stream sampling program in Virginia.
- NVPDC analyzed **18,099** stream temp. samples **from 1986 to 1997**.
- 2623 samples were not used (lakes, interference from point sources, etc.).

1998 NVPDC Analysis of Fairfax Co. (VA) Water Quality Database

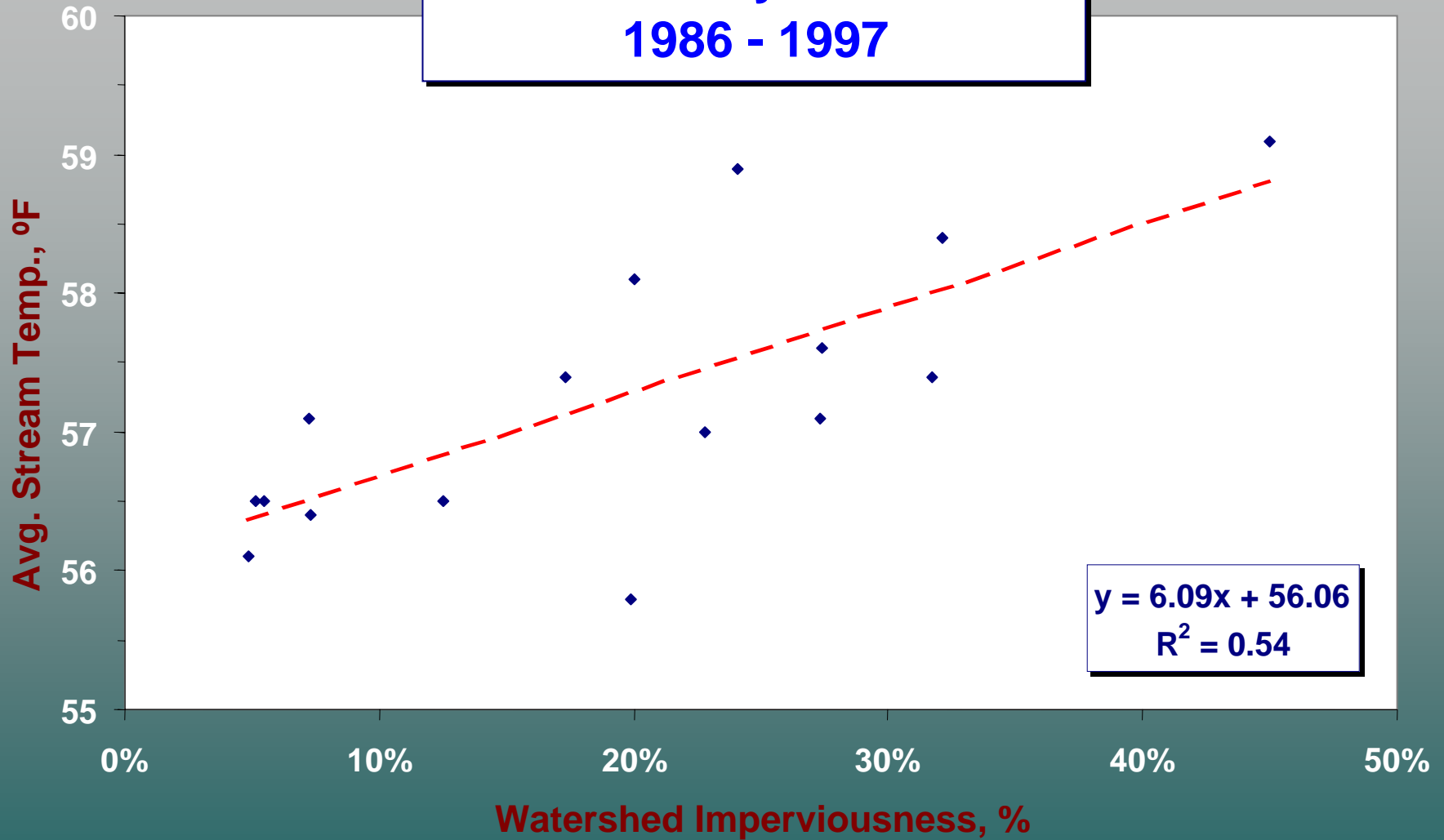


Average Year-Round
Stream Temp., °F





Fairfax County Watersheds 1986 - 1997



Over 15,000 temperature samples taken by the Fairfax County Health Department, 1986 - 1997



New NVPDC analysis of Fairfax Co. water quality database

- A trend was found ($R^2 = .54$, $n = 15,467$) correlating impervious cover with elevated stream temperatures.
- Relationship is: *average year-round stream temps. increase by 0.06 °F for every 1% increase in imperviousness.*

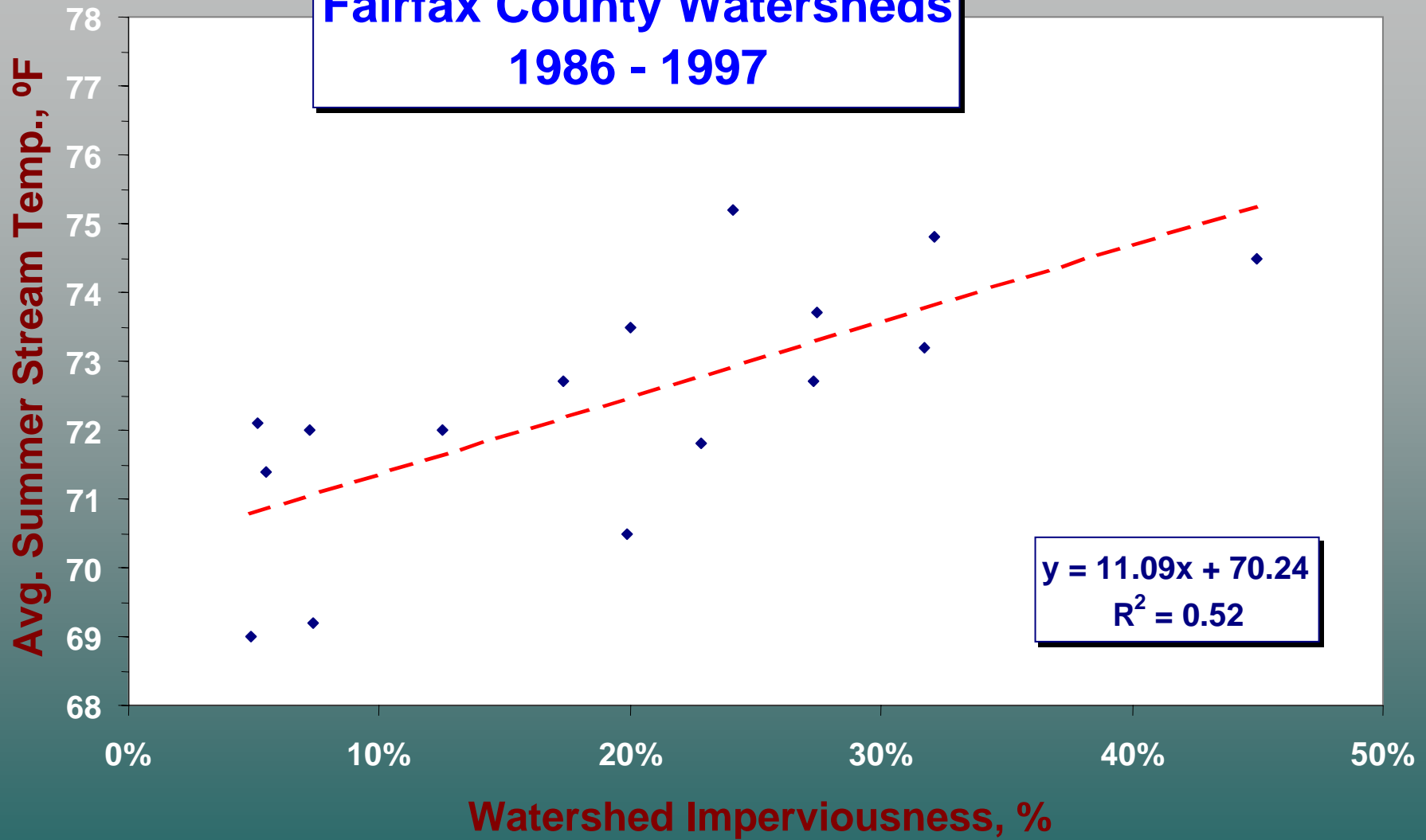


NVPDC & MWCOCG Analyses

- NVPDC found: *average year-round stream temps. increase by 0.06 °F for every 1% increase in imperviousness.*
- MWCOCG found: *average summer stream temps. increase by 0.14 °F for every 1% increase in imperviousness*
- Do these 2 findings point to an increased summer effect? *NVPDC isolated summer impacts from FCHD dataset.*



Fairfax County Watersheds 1986 - 1997

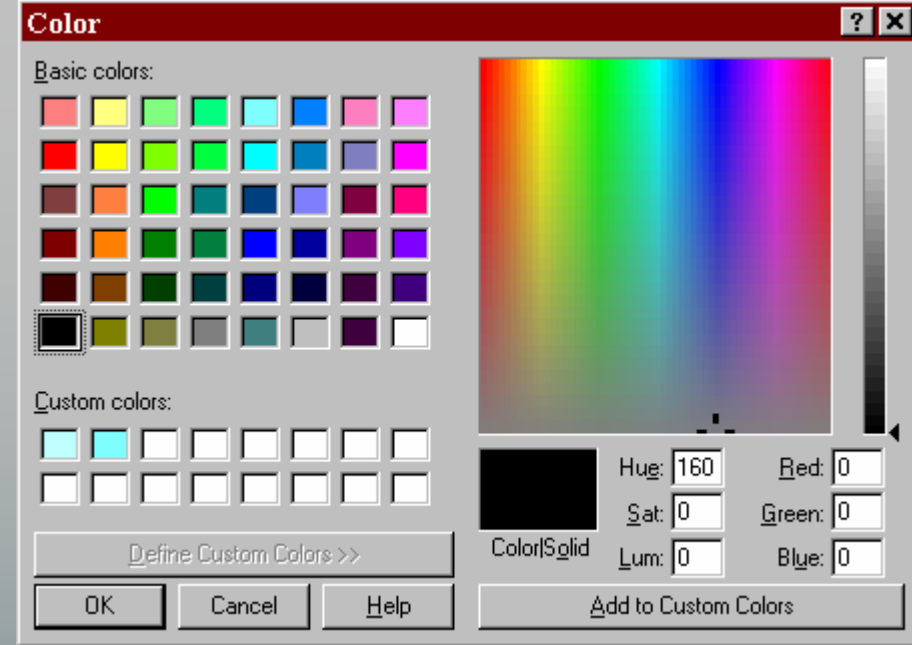




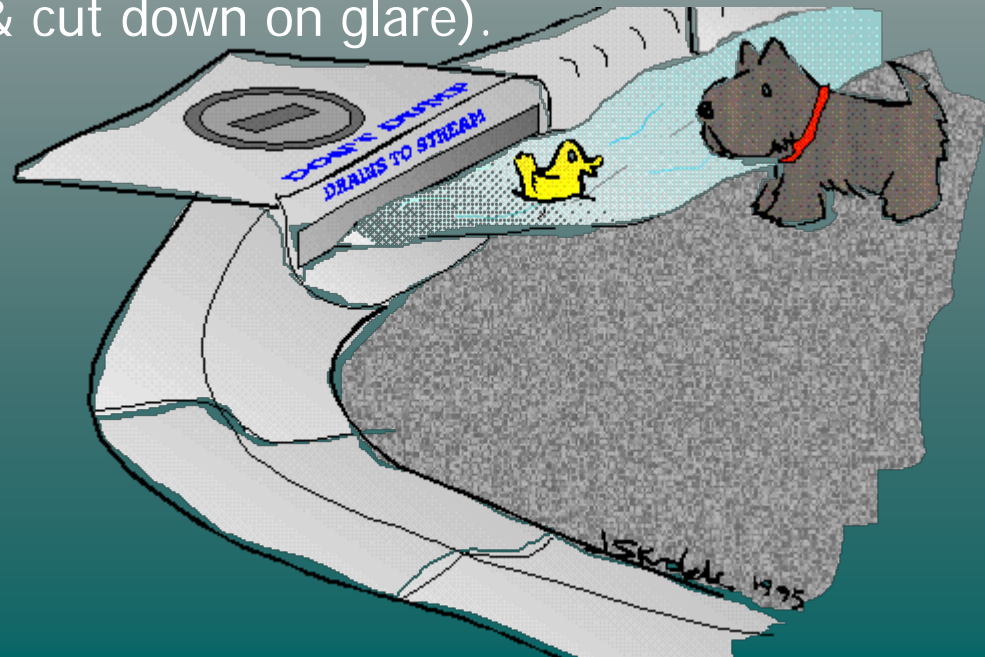
NVPDC Analysis, cont.

- NVPDC found: *average summer stream temps. increase by 0.11 °F for every 1% increase in imperviousness.*
- NVPDC's findings corroborate with MWCOCG's findings.
- Additionally, NVPDC's findings point to an increased summer effect. *Heat pollution impacts are greatest in the summer; nearly double the year-round impacts.*

Factoids

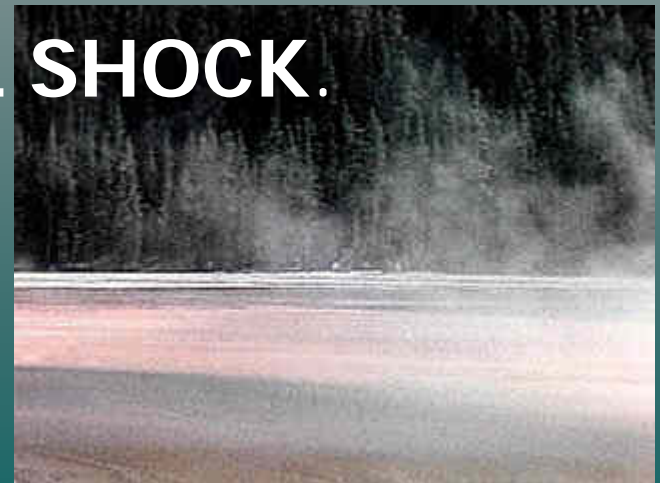


1. Color theory: light surfaces reflect heat; dark surfaces absorb heat (& cut down on glare).
2. Water transfers heat more effectively than nearly all common liquids. (Only ammonia is more effective.)



Thermal Shock; the Missing Link

- Sun's heat is stored in parking lots & streets (esp. on warm, sunny days).
- After summer squalls, storm drains inject this heat into streams.
- The result is **THERMAL SHOCK**.





1998 NVPDC Analysis of Fairfax Co. Water Quality Database

- A trend was found ($R^2 = .58$, $n = 15,467$) correlating impervious cover with amount of time a stream stays over 80°F.
- Pristine watersheds yield streams with base-flows that rarely get above 80°F*.

(* Caveats: in Northern Virginia's climate, if there are no lakes or large ponds in the watershed.)



1998 NVPDC Analysis of Fairfax Co. Water Quality Database

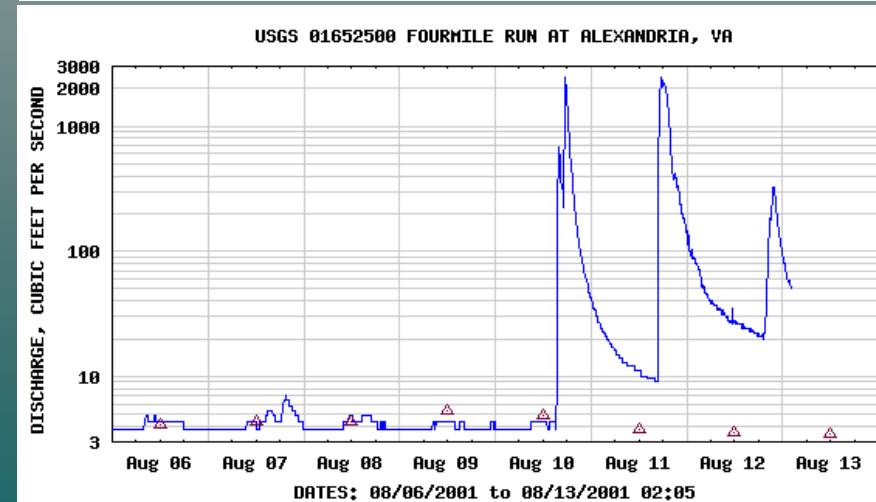
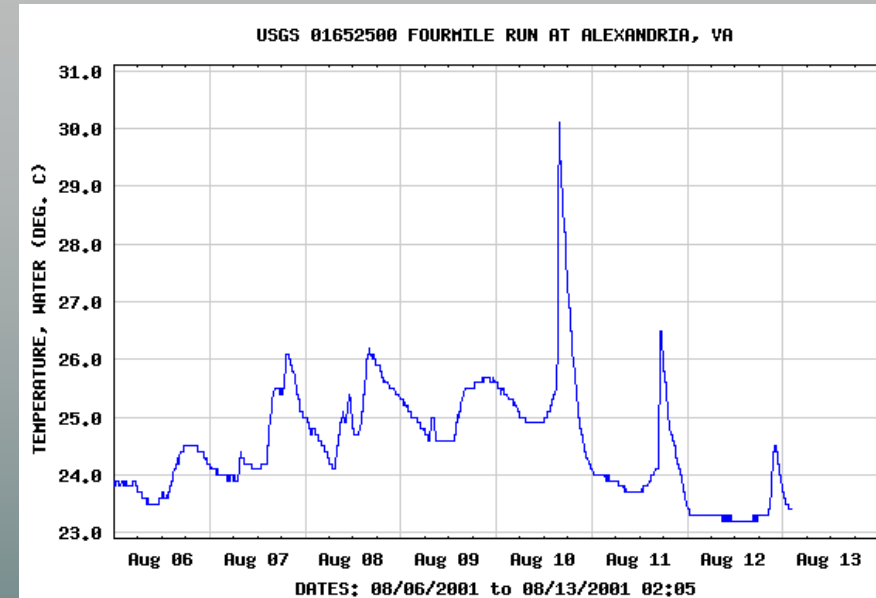
- The amount of time that stream temperature is over 80°F increases by ~1.3% for every 10% increase in watershed imperviousness.

at 10% imperv., stream is over 80°F for 1.1% of time;

at 40% imperv. --> 5.0% of time

Research Needs

1. Storm sampling of temperature is vital.
2. Causation should be isolated (surface color, impervious cover shading, stream shading, etc.).
3. Mitigation techniques should be tested.



EXPLANATION

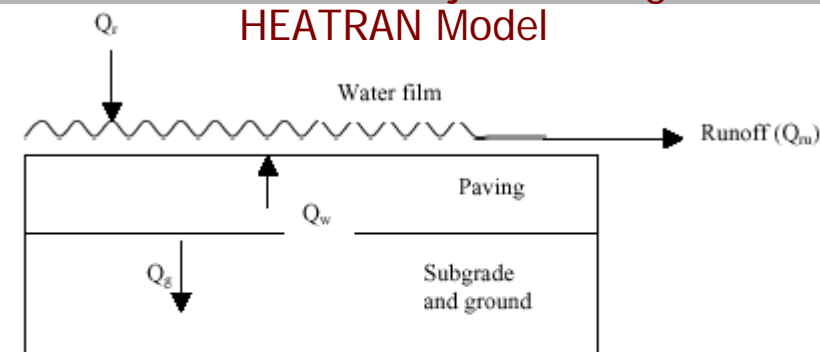
— DISCHARGE

△ MEDIAN DAILY STREAMFLOW BASED ON 25 YEARS OF RECORD

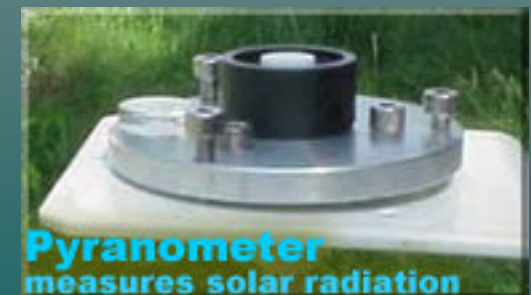
Recent Research

Dr. Bill James & Yi Li,
Univ. of Guelph (Canada),
for Kieser & Associates,
WERF Grant, Published 2004
*Stormwater Thermal Enrichment
in Urban Watersheds*

Consolidated Drain Project, Portage, MI HEATRAN Model



Simplified heat budget schematic during continuous rainfall, day time.
(James and ul Haq, unpublished information 2001)



Dr. Bill James, Permeable Paver Researcher

Published or co-published over 30 technical
articles on permeable pavers

At least 10 focus
on thermal
benefits

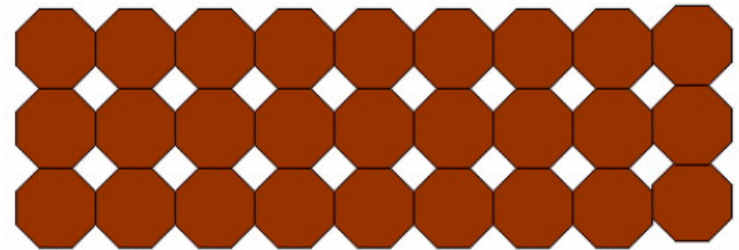


Figure 1. Schematic of Ecostone permeable concrete block paving stone pavement (Gerrits, 2001).

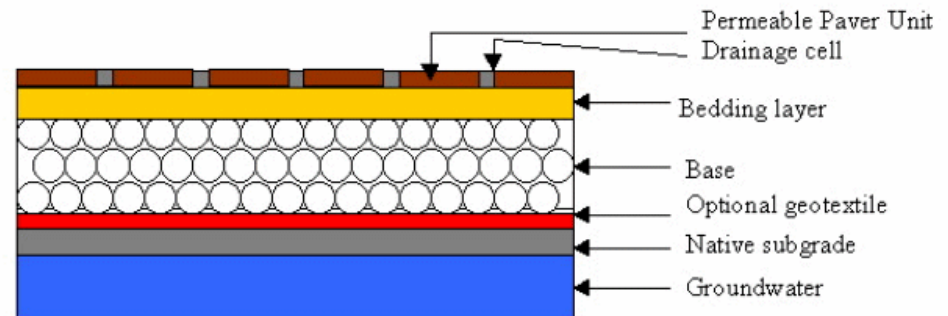


Figure 2. Sectional view of a permeable concrete block paving stone pavement (Gerrits, 2001).



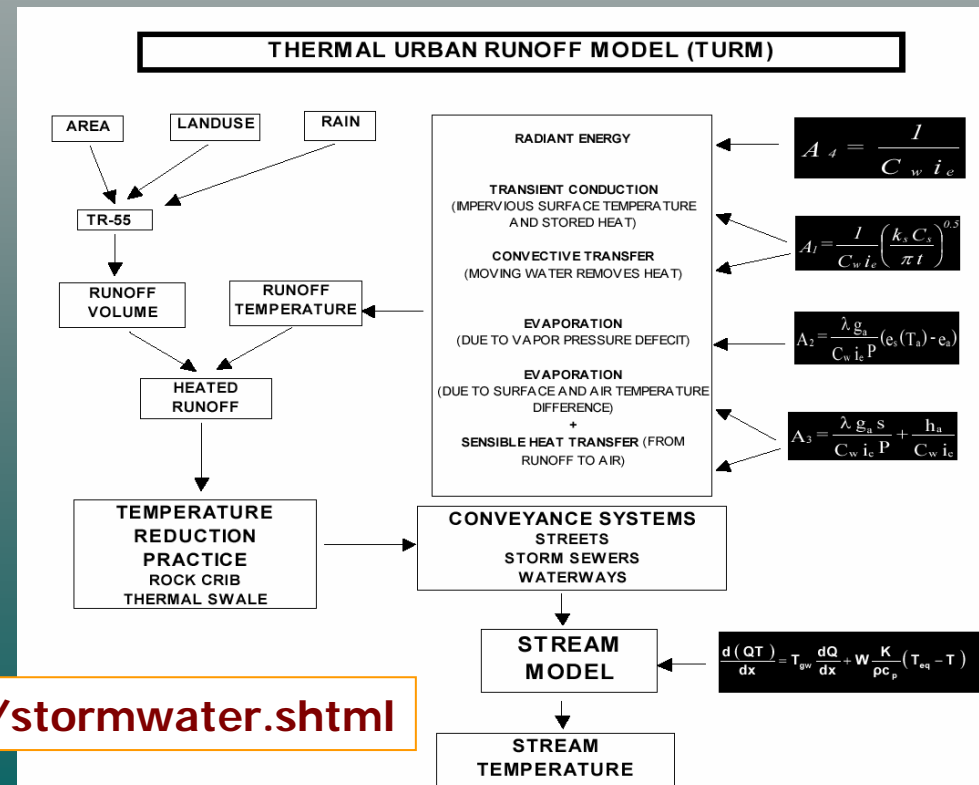
Dane Co., Wisconsin

Regulates “thermally sensitive areas” with thermal runoff mitigation requirements, 2002 Stormwater Management Ordinance

Goal: protect cold water fisheries

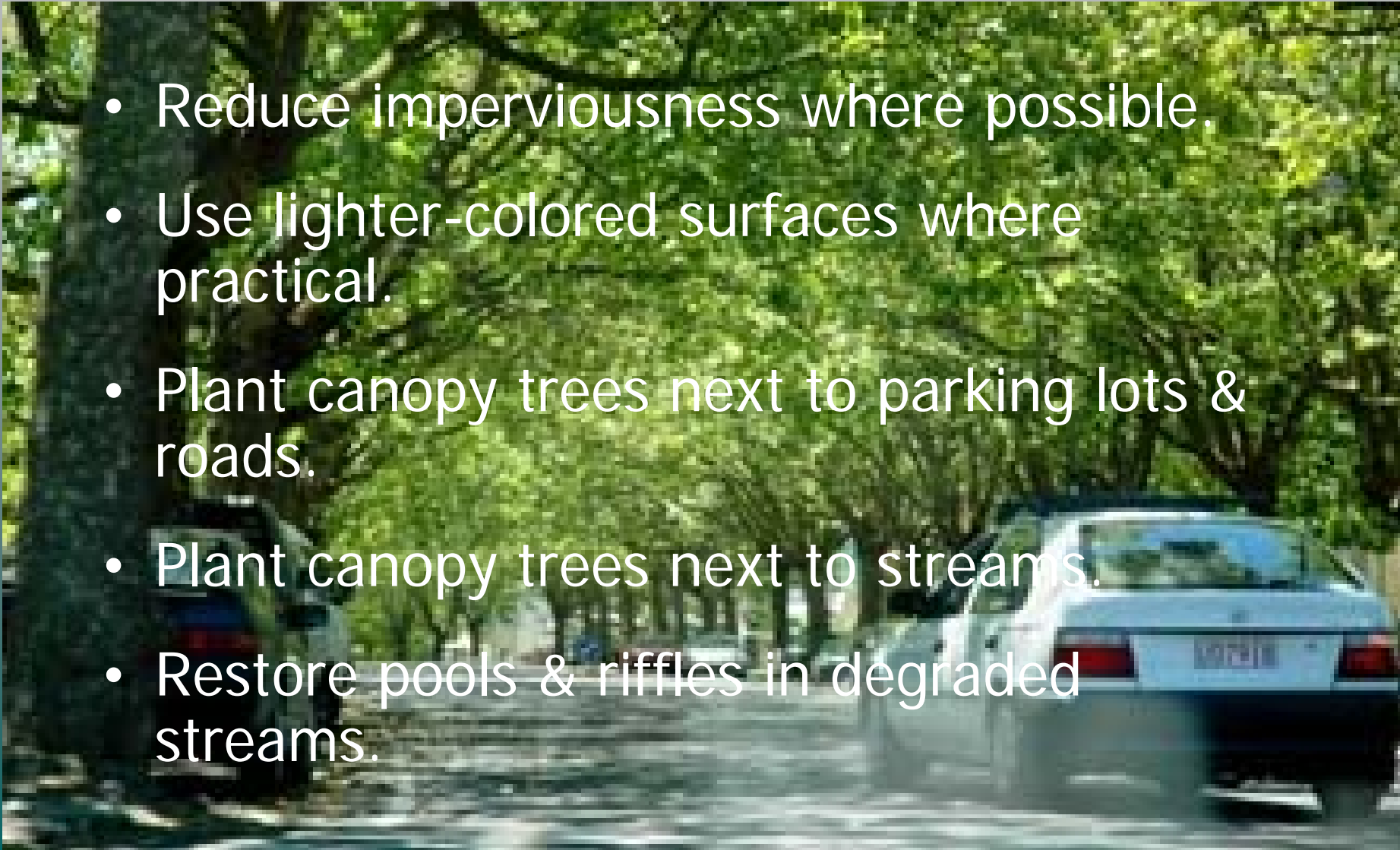
U. WI, Madison
Excel Spreadsheet
Model

www.countyofdane.com/lwrld/lakes/stormwater.shtml



Mitigation Strategies

- Reduce imperviousness where possible.
- Use lighter-colored surfaces where practical.
- Plant canopy trees next to parking lots & roads.
- Plant canopy trees next to streams.
- Restore pools & riffles in degraded streams.





Mitigation Strategies, BMPs

- Most ponds exacerbate heat pollution. (Exceptions: 1. detention dampens thermal shock; 2. Regional ponds with depth-controlled releases).
- Favor infiltration-type BMPs* for on-site control when other considerations are equal. (*porous lots, trenches, sand filters)

Low Impact Development!



Mitigation Examples

Jennings-Randolph Lake & nearby Savage Reservoir in Maryland...

**Army Corps of Engineers mixes water from different depths of the reservoirs & release water of uniform temperature & pH.
(to mitigate acid mine drainage)**

Result...

- **Brown & Brook Trout population exploded;**
- **World-class whitewater venue created.**



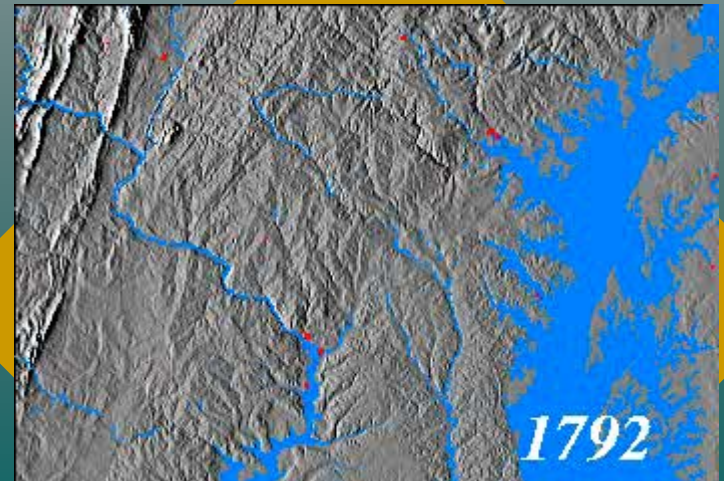
Conclusions

- Heat pollution:
 - is real & measurable
 - has impacts
 - is not well regulated or enforced by statute
 - can be mitigated
- Simple, inexpensive research should be conducted:
 - to determine dominant factors
 - to develop/improve mitigation strategies

Good News

Thermal shock seems to be limited to urban/
suburban areas

Bad News



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